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ABSTRACT

This study sought to examine why peer interaction can facilitate learning, with the hypothesis that collaborative learning provides a social context that is conducive to the generating of explanations (an activity positively associated with learning). Individualistic and collaborative learning contexts were compared for 96 college students (19 male, 77 female) instructed either to "talk aloud" or to "explain" as they learned about the human circulatory system from a text (a 2x2 design). Although the subjects in the two learning contexts did not differ in learning scores, generating explanations (defined as new inferences that went beyond the text material) was highly predictive of both factual and conceptual learning. Motivation and other types of talk were also examined. Motivation was related to factual learning but not conceptual learning. An attachment contains the instructions to subjects in the learning study. (Contains 2 figures and 12 references.) (Author/SLD)

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COLLABORATIVE vs INDIVIDUAL LEARNING AND THE ROLE OF EXPLANATIONS

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ABSTRACT

This study sought to examine why peer interaction can facilitate learning, with the hypothesis that collaborative learning provides a social context that is conducive to the generating of explanations (an activity positively associated with learning). We compared Individualistic and Collaborative learning contexts and instructed college students to either "talk aloud" or to "explain" as they learned about the human circulatory system from a text (2x2 design). Although subjects in the two learning contexts did not differ in learning scores, generating explanations (defined as new inferences that went beyond the text material) was highly predictive of both factual and conceptual learning. Motivation and other types of talk were also examined; motivation was related to factual learning but not conceptual learning.

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PURPOSE

Individuals often learn better if they have the chance to discuss material with one or more peers (collaborative learning) than if they attempt to learn the material alone (individualistic learning). However, relatively little research has examined the question of why peer interaction can produce a learning benefit. This study explored possible underlying mechanisms of a collaborative learning benefit.

BACKGROUND

According to researchers who have studied what goes on during peer interactions (Behrend, 1990; Kruger, 1993; Kruger & Tomasello, 1986; Okada, 1994; Teasley, 1993; Webb, 1982, 1983, 1984, 1992), subjects who engage in explanatory activities--such as generating explanations or hypotheses, making plans and/or predictions, and providing justifications--achieve the greatest learning gains. It may be the case that peers working together to learn material are more likely to engage in explanatory activities than individuals learning the same material alone. Chi and her colleagues (Chi, De Leeuw, Chiu, & LaVancher, 1994) have found that individuals learning on their own benefit substantially when they are explicitly prompted to provide self-explanations. Researchers have concluded that individuals learning alone typically do not automatically elaborate or explain material to themselves but are able to do so if prompted or trained; subsequently, they show higher learning scores (Garner, 1987; Pressley, Wood, Woloshyn, Martin, King, & Menke, 1992).

Collaborative learning may provide a natural context for producing explanations. Those who engage in conversation are motivated to establish mutual knowledge, meaning that they attempt to monitor each other's understanding in order to ensure that they are communicating effectively. As a result of this implicit conversational goal, participants may be more likely to explain their own understanding and to request explanations from the others. Thus, increased explanation generation may be a critical mechanism underlying learning during peer interaction.

We chose to examine the explanations produced during both individualistic and collaborative learning conditions and also attempted to manipulate explanation

generation in a direct way. By doing so, we hoped to determine whether the generation of explanations directly influenced learning outcomes in the two contexts.

METHODOLOGY

Although this study focused on explanations, other types of talk (summaries, rehearsals) and factors such as motivation were monitored as well. College students learned material from a text either alone or in dyads, and half of each condition was explicitly instructed to explain the material while the other half was instructed simply to talk aloud as they learned. All subjects were given individual pre- and posttests. (NOTE: we are interested in whether individual learning scores are affected by learning context, not in comparing group performance to individual performance).

DEFINITION OF EXPLANATION

In order to capture explanations produced by subjects working alone as well as those produced in a collaborative setting, we based our definition of an explanation on Chi et al's (1994) definition of a "self-explanation." That is, an explanation is a new inference that goes beyond the simple meaning of the text. Specifically, an explanation can be:

- a connection between current text information and information in previous portions of text
- a connection between current text information and prior knowledge
- a new inference about a component of the system being studied
- a new inference about the system as a whole

DESIGN OF STUDY - 2x2 Between Subjects

		Learning Context: Individuals	Learning Context: Dyads
Instructions	Talk Aloud	16	16 (32 Ss)
	Explain	16	16 (32 Ss)

SPECIFIC QUESTIONS:

- Will subjects who learn in dyads ("Dyads") show greater learning gains than those who learn alone ("Individuals")?
- Will subjects explicitly instructed to explain ("Explain") show greater learning gains than those who are instructed to simply talk aloud ("Talk aloud")?
- Does generating explanations foster learning?
- Do other types of talk (summaries, rehearsals) or motivation levels appear to influence learning in these contexts?

MATERIALS

TASK: Students learned about the human circulatory system by reading a 1,000-word excerpt from a high-school biology textbook (Towle, 1989; identical to that used in Chi et al, 1994).

TEXT: The text was presented in 49 segments (i.e., 49 separate pages) such that subjects read only 1-2 sentences at a time; this encouraged talk and prevented one member of a dyad from reading ahead of the other. Subjects read each text segment aloud (those in dyads took turns reading aloud) and then talked about that text segment.

GOAL: The overall goal was to learn the parts of the circulatory system and how the system as a whole functioned.

SUBJECTS

Subjects were 96 undergraduate students (19 males, 77 females) at the University of Pittsburgh who had not taken any biology courses. Subjects were recruited through campus advertisements and paid $10 for their time; each session lasted approximately 2½ hours.

PROCEDURE

PHASE 1 - Pretest

- All subjects took a pretest to assess their prior knowledge of the circulatory system (see Measures section below).

PHASE 2 - Instructions and Practice

- Subjects were randomly assigned to a condition.
- Those in Talk aloud conditions were *instructed to talk aloud as they tried to understand and learn from the text.*
- Those in Explain conditions were explicitly *instructed to explain the material in as much detail as they could by making connections and drawing inferences.*
- All subjects went through a short *practice text* (on electric circuits) to make sure they understood the procedure and followed their instructions.

PHASE 3 - Learning Session (videotaped)

- Subjects were then given the experimental text on the circulatory system to work on at their own pace.
- Subjects could take notes or draw diagrams but could not use these on the posttest; they were also allowed to turn back to previous pages of text.

PHASE 4 - Learning & Motivation Measures

- Subjects completed a motivation questionnaire and a posttest and answered a set of questions about the circulatory system.
- Subjects were then paid and debriefed.

MEASURES

- PRETEST - define 14 terms, draw diagram of circulatory system - scored by using a master checklist to tally the number of correct facts subjects express about the circulatory system - 84 points possible (Interrater Agreement > 90%)

- POSTTEST - a "factual learning" measure - identical to pretest - 84 points possible

- FINAL REPRESENTATION of the path of blood flow in the circulatory system, based on subjects' final diagram - scored as correct or incorrect

- QUESTIONS - a "conceptual learning" measure - 16 questions about the circulatory system that require application and synthesis of information - scored by comparison to "ideal" answer provided by med student (each full, partial, or no credit) - 32 points possible

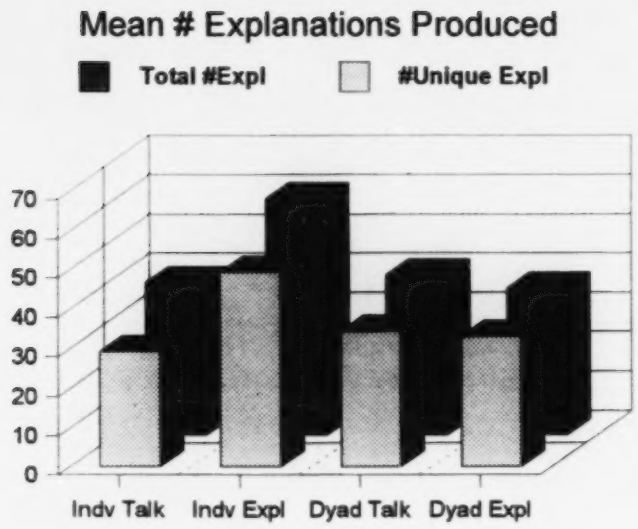
- MOTIVATION LEVEL - 4-item, likert scale questionnaire with higher numbers indicating higher motivation and enjoyment of task - 28 points possible

- TIME spent learning the circulatory system, in minutes
- NUMBER OF WORDS spoken during learning session, per person (Dyad numbers calculated by dividing total number of words by two)
- TOTAL NUMBER OF EXPLANATIONS generated during the learning session, per person (Agr. ≈ 85%)
- NUMBER OF UNIQUE EXPLANATIONS generated during the learning session (total number minus any repeated explanations), per person
- Number of text segments during which a subject produced a SUMMARY/RESTATEMENT of the text (Agr. ≈ 90%)
- Number of text segments during which a subject produced a REHEARSAL of the path of blood flow, listing at least three consecutive components (Agr. > 95%)

RESULTS

NOTE: Because scores from members of a dyad are not independent, one member was randomly chosen to represent each cell value for the Dyad conditions.

- No collaborative learning benefit was found - a 2x2 ANCOVA on Posttest scores and Question scores (with Pretest scores as covariable for each) showed no significant differences between Individual and Dyad learning conditions.
- Those in the Explain conditions did tend to generate more explanations - 2x2 ANOVAs on Number of Unique Explanations showed Explain > Talk conditions ($p=.08$).
- However, there was a significant interaction for explanations generated, such that Individuals instructed to Explain generated many more explanations than subjects in the other conditions (see Bar Chart, next page).
- Subjects in the Explain conditions scored significantly higher on the Questions than subjects in the Talk aloud conditions according to a 2x2 ANCOVA on Questions (with pretest scores as covariable), $p=.03$.



Linear Regression on POSTTEST
(Factual Learning)

Predictors	R^2	
Pretest only (p<.0001)	.4180	
Pretest + Motivation level (p=.03)	.4608	4%
Pretest + Unique Explanations (p=.009)	.4791	6%
Pretest + Total Explanations (p=.002)	.5033	8.5%
Pretest + Rehearsals (p=.0008)	.5175	10%

Not Significant: Number of Words, Summary/restatements, and Time

Linear Regression on QUESTIONS
(Conceptual Learning)

Predictors	R^2	
Pretest only (p<.0001)	.3730	
Pretest + Unique Explanations (p=.004)	.4541	8%
Pretest + Total Explanations (p=.004)	.4526	8%

Not Significant: Motivation, Rehearsals, Summary/restatements, Number of Words, and Time

- The production of Explanations did account for a significant amount of variance in learning scores (see Regression Table, previous page). Rehearsals was the strongest predictor for Posttest scores, but was not related to Question scores. In contrast, Total Explanations was a strong predictor of both Posttests and Questions.
- Individuals summarized the text and rehearsed the blood path more often than Dyads (2x2 ANOVA, $p<.0001$ and $p=.01$, respectively); Those told to Talk aloud summarized the text more often than those told to Explain ($p=.01$).
- The four conditions did not differ significantly in Pretest scores, Motivation levels, or Time; Individuals produced about 1.5 times more words than those learning in a Dyad.
- Subjects who produced many Unique Explanations (the top ⅓) were more likely to have a correct Final Representation of the circulatory system than those who produced few Unique Explanations (the bottom ⅓) - Fisher's (2-tailed) exact test = .03.
- Overall means (and s.d.) are as follows:

Pretest	15.5 (7.3)	Questions	12.6 (5.9)
Posttest	49.2 (15.6)	Motivation	21.1 (4.0)
Time (min)	36.2 (10.9)		

CONCLUSIONS

- Our study did not show a collaborative learning benefit, but our findings do not rule out explanation production as a potential underlying mechanism in the collaborative learning benefit.
- Generating explanations was strongly associated with both factual and conceptual learning gains, accounting for 8.5% and 8% of the variance, respectively. In addition, those who produced high levels of explanations were more likely to attain a correct final representation of the circulatory system.

- Motivation was mildly associated with factual learning but not conceptual learning. Rehearsing the path of blood flow was greatly associated with factual learning gains but not at all with conceptual learning gains. Factors such as Number of Words produced, Time spent on learning, and Summarizing/restating the text were not associated with learning gains.
- Individuals responded dramatically when instructed to Explain, compared to Dyads who did not appear to respond at all. Either explanation generation is simply too difficult to coordinate with management of a social interaction, or Individuals were simply more likely to follow through with the instructions. In any case, our results suggest that it is beneficial to instruct students who work by themselves to verbally explain the material (specifically by making connections and drawing new inferences).

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Instructions to Subjects of Learning Study

BACKGROUND: The purpose of the study we are conducting is to compare two learning contexts: learning material alone and learning material in pairs (that is, with a study partner). We are also interested in whether certain types of instructions help people learn better. [tell Ss whether they are in Dyad or Individual condition]

The topic you will be learning is the human circulatory system. First, you will complete some worksheets about the circulatory system so we can see what you already know about the topic. Then I will give you a text about the circulatory system and some specific instructions about how you should approach this learning task. There will be a short practice session too so that you can get comfortable with the presentation format. I will be recording your study session, which will last about 30 minutes. Then you will answer some more written questions, so that I can assess your final understanding of the topic. [FOR DYADS: Although you will be learning the material together, you will be answering all the written questions individually.]

Pretest administered

ALL: Today you will learn about the human circulatory system. The goal will be for you to achieve a deep and accurate understanding of the circulatory system–that means what the parts are, how they each work, how the system as a whole works, and what its purpose is. I'm going to be giving you some specific instructions on how you are to go about learning this topic.

In learning about the circulatory system, you will be reading excerpts from a biology textbook. The text will be presented just one or two sentences at a time so that you can really think about each new piece of information and how it fits into your understanding of the circulatory system. [FOR DYADS: Also, it is important for you two to work together as a team to help each other learn the material]. You are allowed to look back at previous sentences, and you may take notes or draw pictures if you think this will help you; however, at the end when your learning is assessed, you will not have access to the text or to any notes you take.

In order to make sure that you understand the procedure and are comfortable with it, I am going to have you go through a practice session. You will read a short text about electrical circuits which will be presented a sentence or two at a time, just like the circulatory system text will be presented.

TALK ALOUD INDIVIDUAL: Since we are interested in exactly how people learn material from text, we need to know what goes on in their minds as they are learning. To do this, we use what is called the "think aloud" technique. What I'd like you to do is as you read each line of text, say out loud what you are thinking. Just say whatever is going through your mind as you try to understand and learn the material, even if it seems unimportant or obvious.

Practice session prompts:

* Spend some more time on each line and say out loud what you are thinking as you learn it (if subjects spend less than 12 seconds on a line)
* Say out loud what you are thinking even if it seems unimportant or obvious
* What are you thinking about right now? (if subjects are silent for more than 10 seconds)
* Please speak up (if subjects whisper or mumble)

TALK ALOUD DYAD: What I'd like you to do is to read each line of text and then spend some time discussing it. For example, tell each other what's going through your mind and help each other try to understand and learn the material.

Practice session prompts:

* Spend some more time discussing each line (if subjects spend less than 12 seconds on a line)
* Tell each other what you are thinking (if subjects are silent for more than 10 seconds)
* Please speak up (if subjects whisper or talk too softly)

EXPLAIN INDIVIDUAL: What I'd like you to do is to read each line of text and then explain out loud in as much detail as you can what that line means to you and how it fits into your current understanding of the topic. For example: (1) you might say how that line connects to facts you might already know about the topic, (2) you might say how it connects to information given in previous lines, (3) you might say what inferences it allows you to make about the components of the system, or (4) you might say what inferences it allows you to make about the system as a whole. In other words, make as many connections and inferences as you can as you build an understanding of the topic.

Practice session prompts for the Explain Individual condition:

* Spend time explaining each line

If subjects do not generate an explanation, one of the following prompts will be given:

* Make a connection between that information and something you already knew
* Make a connection between that information and what you've already read
* Say something new about a component of the system--it's structure, behavior, or function
* Say something new about the system as a whole--what it does or doesn't do

(subjects will be encouraged to generate at least one explanation per line of text)

EXPLAIN DYAD: What I'd like you to do is to read each line of text and then together explain in as much detail as you can what that line means and how it fits into your current understanding of the topic. For example: (1) you might say how that line connects to facts you might already know about the topic, (2) you might say how it connects to information given in previous lines, (3) you might say what inferences it allows you to make about the components of the system, or (4) you might say what inferences it allows you to make about the system as a whole. In other words, work together to make as many connections and inferences as you can as you build an understanding of the topic.

Practice session prompts for the Explain Dyad condition:

* Spend time explaining each line

If subjects do not generate an explanation, one of the following prompts will be given:

* Make a connection between that information and something you already knew
* Make a connection between that information and what you've already read
* Say something new about a component of the system--it's structure, behavior, or function
* Say something new about the system as a whole--what it does or doesn't do

(subjects will be encouraged to generate at least one explanation per line of text)

Subjects are then given the experimental text on the circulatory system and told to go through it in the same manner. They are not given any prompts during this learning session (in fact, the experimenter leaves the room).

MOTIVATION MEASURE

Subjects circled a number representing their answers to each of the following four questions:

How interested are you in the topic of the circulatory system?

NOT INTERESTED	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*VERY INTERESTED*

How enjoyable was the learning session (when you learned about the circulatory system through reading and talking)?

NOT ENJOYABLE	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*VERY ENJOYABLE*

How much would you enjoy doing the learning session again sometime with a different topic?

NOT AT ALL	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*VERY MUCH*

Would you recommend the learning format that you participated in for other students trying to learn this material?

NOT AT ALL	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*YES DEFINITELY*

DEFINITION OF TERMS USED ON PRETEST AND POSTTEST

Subjects were asked to write down everything they currently knew about each term. Each page was headed with a list of questions to guide their thinking:

Think about the following:

- *What kind of thing is it? What does it refer to?*
- *Where is it found in the body?*
- *What is its structure, texture, or composition?*
- *What does it do?*
- *What is its purpose with regard to the circulatory system?*

Explain everything you know about _____

There were two terms on each page, with space underneath each to write. Complete list of Terms:

artery	*atrium*	*capillary*	*diffusion*	*heart*	*pulmonary circulation*
aorta	*ventricle*	*blood*	*lungs*	*septum*	*systemic circulation*

DRAWING A DIAGRAM OF THE PATH OF BLOOD FLOW (PRETEST AND POSTTEST)

Subjects were given an outline of the human body and asked to draw the path of blood flow throughout the body. They were provided with colored pens and a pencil. Those who attained a correct Final Representation showed knowledge of the heart being a double pump (one side pumps blood to lungs, then returns to opposite side to pump blood to body) with all parts correctly labeled.

QUESTIONS (Measure of Conceptual Learning)

Taken from Chi et al. (1994)

1) Which artery carries deoxygenated blood?

2) How can we tell whether a blood vessel is a vein or an artery, on the basis of its purpose?

3) Why don't we have valves in pulmonary veins?

4) Doctors warn against having too much cholesterol in your diet, because it builds up on the lining of the coronary artery and clogs it. What happens to the heart if the coronary artery is blocked?

5) What is the difference between blood pressure and pulse rate?

6) What is it that you are feeling when you take your pulse?

7) Why does the circulatory system need an atrium? In other words, why does each side of the heart need two chambers instead of just one?

8) The short-term effect of exercise is a faster heart beat. However, the long-term effect of exercise is a slower heart beat. Why?

9) In which kind of blood vessels (arteries, veins, or capillaries) is the blood pressure the lowest? Why?

10) When we get our blood pressure taken at the doctor's office, they read us two numbers, such as 120/80. The upper number measures the systolic pressure, and the lower number measures the diastolic pressure.

    A) What do these numbers measure?

    B) Why is the upper number larger than the lower number?

    C) Why is it dangerous for the upper number to be too high?

11) What symptoms might you experience if you had a hole in your septum, and why?

12) When you put a cube of sugar in a glass of water, the sugar molecules will diffuse throughout the water until they are equally distributed and a state of equilibrium is reached. Why ISN'T a state of equilibrium reached in the human body between the molecules of oxygen in the blood and the molecules of oxygen in the body cells?

13) Why is your right ventricle less muscular than your left ventricle?

14) Why do people who have poor circulation also have cold feet or hands?